REMARKS

This paper is reponsive to an Official Action that issued in this case on November 1, 2006. In that Action, the Office:

- Finalized a restriction requirement, and, as a consequence, withdrew claims 13-20 from consideration.
- Rejected claims 1, 3, 4, and 6 under 35 USC §112, ¶2.
- Rejected claims 1, 2, 4, 5, 11, and 12 under 35 USC §103 as being obvious over U.S. Pat. No. 4,391,036 to Kishimoto in view of U.S. Published Pat. Appl. No. 2005/0042512 to Ferreira.
- Rejected claims 6-10 under 35 USC §103 as being obvious over Kishimoto in view of U.S. Pat. No. 4,317,872 to Varma and further in view of Ferreira.

In response, applicants respectfully traverse the rejections and request reconsideration in light of the following comments. Claims 4, 6-8, 10, and 12 have been amended, claims 13-20 have canceled without prejudice, and new claims 21 through 28 have been added. With the exception of claim 4, which has been amended to overcome a Section 112 rejection, the claim amendments are made for the purpose of more particularly pointing out applicants' invention or otherwise improving the form of the claim, as appropriate. As will become clear from the following discussion, the amendments were not necesitated by the cited art.

Rejection of Claims 1, 3, 4, and 6 under 35 USC §112, ¶2

Claims 1 and 6 were rejected as being indefinite because, according the Office, "the acronym AGM does not particularly point out what kind of separator is being claimed." It is very well known to one reasonably skilled in the battery arts that an "AGM" separator is an "absorbent glass mat" separator. Furthermore, this acronym is defined at para. [0039] in the description. As such, these claims are not indefinite. Applicants would prefer not to amend the claim for a reason such as this, but will do so if the Office insists. Claim 6 has, however, been amended to specify "absorbent glass mat" since other changes were made to that claim as well.

The Office rejected claim 3 because, allegedly, "it is unclear … what the desired value of the specific gravity is." Furthermore, according to the Office "[i]t is also unclear how the specific gravity is a function of the voltage."

The specific gravity vs. voltage relationship is given by the "Nernst" equation. More precisely, the Nernst equation expresses the dependence of equilibrium voltage on electrolyte *concentration* – but electrolyte specific gravity and electrolyte concentration are directly related (*see*, *e.g.*, para. [0046]. For the Examiner's convenience, excerpts from two books on batteries are attached. This is all well known to those skilled in the art; if required, a Declaration on this issue from one skilled in the art can be provided.

It should now be clear that the recitation in claim 3 that the "specific gravity of said first gelled electrolyte is at a desired value, after plate formation, as a function of a voltage of said battery" is not indefinite. In other words, the battery voltage *defines* the specific gravity of the first gelled electrolyte.

The Office rejected claim 4 because the term "rapidly" is allegedly a "relative" term. Applicant agrees and hereby amends claim 4 to delete the term "rapidly."

It is believed that the foregoing comments and the amendments overcome the Section 112 rejections. The Office is therefore requested to withdraw the rejection of claims 1, 3, 4, and 6 under 35 USC §112, ¶2.

Art Rejections

It will be helpful to provide a brief background concerning batteries, the applicants' invention and an overview of the cited art before addressing the specifics of the claim language.

Battery Basics

In a VRLA battery, the electrolyte is immobilized. In the prior art, this is typically accomplished in one of two ways. One way is to use a fibrous mat separator, such as an AGM separator. The fibrous mat separator is highly porous and absorbent. It absorbs much of the (liquid) electrolyte that is added to the battery and holds (*i.e.*, immobilizes) it in close contact with the positive and negative plates.

The other way to immobilize the electrolyte is turn it into a gel. The gelled electrolyte is usually formed via a gelling agent, such as silica. Typically, a gelled-electrolyte battery uses a micro-porous leaf separator, which is much less porous than a fibrous mat separator. The high porosity of the fibrous mat separator is not required since, at least in the prior art, the separator is not used to retain electrolyte. In fact, the primary purpose of the leaf separator in prior-art gelled-electrolyte batteries is to separate the plates to avoid shorts.

Another important concept for understanding the present invention is the plate "formation" process. "Formation" is an initial charging process during which the raw paste within the battery plates is electrochemically converted into charged active material, lead dioxide being formed in the positive plates and sponge lead in the negative plates.

Formation is carried out in one of two locations – either (1) in the "jar" or (2) in a "tank." The jar is a container that normally houses one complete battery cell (element and electrolyte). Therefore, in "jar formation," the plates are formed in-situ; that is, they are formed in the battery container proper. On the other hand, in "tank formation," the plates are preformed in large open tanks and then added to the jar.

Summary of Applicants' Claimed Invention

In accordance with the illustrative embodiment of the invention, a silica-electrolyte mixture is added to the "jar" containing an absorbent glass mat separator and unformed plates. The silica, which in the illustrative embodiment is colloidal silica, has a very small particle size. This small particle size enables the silica to physically enter the separator and the unformed battery plates along with the electrolyte.

As added to the jar, the (initial) silica-electrolyte mixture is not a gel; in fact, it is a relatively low specific gravity liquid. In its liquid form, the silica-electrolyte mixture penetrates the separator and the unformed plates. The electrolyte mixture is advantageously added to the jar under vacuum to promote penetration into the separator and plates.

During plate formation, sulfate ion leaves the plates and enters the silica-electrolyte mixture. This increases the specific gravity of the mixture and ultimately causes the silica-electrolyte mixture to gel. The specific gravity of the mixture and the silica concentration are selected so that (1) the mixture when added is not a gel; and (2) the majority of the transformation from fluid to gel occurs shortly after the formation process has ended.

Since the concentration of silica in the mixture is the same within the separator, within the plates, as well as within the various open regions within the jar, gel is formed everywhere. Again, gel is formed *within* the plates and the separator as well as on the outside of the plates and the separator.

Kishimoto and Ferreira

Kishimoto discloses a process for producing a sealed lead-acid battery, which includes an AGM separator. Kishimoto uses a tank formation process, not a jar formation process, to form the plates.

Kishimoto notes the drawbacks of prior-art gelled electrolyte batteries. In particular, Kishimoto notes the high internal resistance and poor discharge characteristic due to the presence of the gel. Kishimoto addresses this by providing a battery in which gel only appears near the periphery of the jar.

In particular, Kishimoto note, at col. 7, lines 10:

> [T]he concentration of the viscosity-increasing agent in the sulfuric acid electrolyte will be made very low in the center part of the plate group and, when a sulfuric acid electrolyte higher in the concentration of the viscosity-increasing agent than the above poured sulfuric acid electrolyte is then poured in … the concentration of the viscosity increasing agent in the sulfuric acid electrolyte will be higher in the peripheral part of the plate group so that the concentration distribution of the viscosity-increasing agent may be such that the sulfuric acid electrolyte of an average concentration … may be well fluid in the center part of the plate group but may be hardly fluid in the peripheral part of the plate group… Thus the seal lead-acid battery according to the present invention has features that the internal resistance will never become so high as a conventional gel type sealed lead-acid battery…

Ferreira discloses a lead acid battery having a gelled electrolyte that is formed by filtration action of an absorbent separator. Ferreira introduces an electrolyte-silica mix into a jar with unformed plates and a separator. The silica is a "never dried precipitated silica slurry." Mean particle diameter is said to be in the range of about 2 to 20 microns for "milled" versions of the silica and in the range of about 10 to 25 microns for "unmilled" versions. (Pg. 2, para. [0019].) The separator and/or the case into which the cells are inserted are specially formed to provide free space between the case and the edges of the plates and the edges of the separator material.

Ferreira discloses that "sulfuric acid is absorbed into the plates and the absorbent, porous filtration medium of the separator material while silica is filtered out of that sulfuric acid." (Page 2, para. [0023].) This enables Ferreira to provide a battery with a "novel electrolyte, some of which is immobilized as a **liquid** in the active material and the separator of the battery and the rest of which is immobilized because it is **gelled in free spaces** between the separator and the positive plate or plates of the battery." (Page. 3, para. [0042], emphasis added.)

In other words, both Kishimoto and Ferreira use the separator as a molecular sieve to concentrate the silica at the periphery of the plates. And that is why neither Kishimoto nor Ferreira disclose the use of colloidal silica for *their* processes. Simply put, the particles in colloidal silica are *too small* to be filtered. Yes, Ferreira discloses the use, in the prior art, of colloidal silica. But neither Kishimoto nor Ferreira can use it in *their own* processes.

Kishimoto and Ferriera want only the electrolyte (or electrolyte with a suitably low concentration of silica) to flow to the interior of the plate or the interior of the separator. This insures that a gelled electrolyte is NOT produced in the plates or in the separator.

Rather, the Kishimoto and Ferreira processes produce gel in any open space between the separator and a plate or between the separator and the edge of the battery case.

This is essentially the opposite of applicants' claimed invention. Applicants select silica with a particularly small particle size (*e.g.*, colloidal silica, *etc.*) to ensure that no such filtration occurs. Rather, the silica-electrolyte mix permeates both the plates and the separator so the gel is formed within the plates and within the separator. In fact, as indicated in the specification at para. [0049]: "[l]ittle or none of first gelled electrolyte **314** is present outside of plates **108** and **110**, and AGM separator **112**; most of the gelled electrolyte **314** is absorbed by those components."

This would certainly seem to be a situation in which the prior art truly teaches away from the claims under consideration.

Varma

Varma discloses a lead acid battery that utilizes a silica-electrolyte mix. The battery also includes a modified separator, which includes a silicate that is integrally mixed with an oxygen compound containing boron.

The chemistry that is used in Varma is different than the chemistry that is used in applicants' claimed invention. In particular, Varma does not rely on the formation process and the concomitant release of sulfate into the electrolyte to trigger the gelling process substantially upon completion of plate formation.

Rather, Varma produces a gelled electrolyte by simply mixing sulfuric acid electrolyte with "Ludox," which is a silica containing compound (produced by DuPont). Gelling occurs independently of the battery chemistry. See, for example, Fig. 2, showing that for about 1 to 6% SiO_2 in the electrolyte mixture, the gel begins to set within the range of about 8 minutes to 1 hour. Since the plate formation time referenced in the Examples is 120 hours, it is clear that the electrolyte gels soon after the formation process has begun and well before it has finished.

Varma notes that his process can be used in conjunction with pre-formed or un-formed plates (*see* col. 7, lines 5-6). *See*, also, Example 2 (gel electrolyte added after formation).

Claim Language

Claim 1 recites, in pertinent part:

> mixing (i) silica and (ii) an electrolyte containing sulfuric acid to form a first silica-electrolyte mixture … wherein a particle size of said silica is less than 100 nanometers;
>
> contacting said first silica-electrolyte mixture with said plates and said AGM separator; and
>
> forming said plates by applying current thereto, wherein during and after said plates are formed, said first silica-electrolyte mixture gels to form a first gelled electrolyte.

Neither Kishimoto nor Ferrieira, alone or in combination, disclose or suggest what is recited in claim 1. Namely, these references do not suggest the use of silica having a particle size that is less than 100 nanometers. As previously discussed, both these references rely on a filtering effect to prevent silica from entering the separator or the plates. If silica with a particle size of less than 100 nanometers were used, the filtering would not occur.

It is noted that Varma provides nothing relevant to claim 1, either. In particular, Varma gels the electrolyte well before plate formation is complete.

In view of the foregoing, it is believed that claim 1 is allowable over the art of record. The Office is therefore requested to withdraw the rejection of claim 1. Claims 2 though 5 are allowable based on their dependence on claim 1. Furthermore, the recitation of additional patentable features in claims 2-5 provides a secondary basis for their patentabilty.

As amended, claim 6 recites, in pertinent part:

> contacting and penetrating an absorbent glass mat separator and plates of said battery with a first silica-electrolyte mixture, wherein said first silica-electrolyte mixture comprises (i) colloidal silica and (ii) an electrolyte containing sulfuric acid, and wherein silica as SiO_2 is in a range of 1.0 percent to 8.0 percent by weight of said first silica-electrolyte mixture;
>
> gelling said first silica-electrolyte mixture by forming said plates

Neither Kishimoto, Ferrieira, nor Varma, alone or in combination, disclose or suggest what is recited in claim 6. Namely, these references suggest neither (1) penetrating an absorbent glass mat separator and plate with a first silica-electrolyte mixture, nor (2) gelling the first silica-electrolyte mixture by *forming the plates*.

In particular, Ferreira filters silica out of the electrolyte that enters the plates. And neither Kishimoto nor Varma gel a silica-electrolyte mixture as a consequence of forming the plates.

In view of the foregoing, it is believed that claim 6 is allowable over the art of record. The Office is therefore requested to withdraw the rejection of claim 6. Claims 7 though 12 are allowable based on their dependence on claim 6. Furthermore, the recitation of additional patentable features in claims 7-12 provides a secondary basis for their patentabilty.

New claims 21 through 28 have been added and are believed to be patentable. Independent claims 21 and 25 are discussed below.

New claim 21 recites:

> contacting and penetrating an absorbent glass mat separator and unformed plates of a battery with a silica-electrolyte mixture, wherein the silica-electrolyte mixture has the following characteristics:
>
> (a) a particle size of the silica in the silica-electrolyte mixture is suitably small so that the silica is not filtered by the separator or the plates;
>
> (b) the silica-electrolyte mixture will not gel before formation of the plates;
>
> (c) the silica-electrolyte mixture gels due to an increase in its specific gravity from sulfate that is released during formation of the plates; and
>
> forming the plates by applying current thereto.

None of the cited art, whether alone or in combination, discloses or suggests what is recited in new claim 21. In particular, none of the references suggest penetrating an AGM separator or unformed battery plates with a silica-electrolyte mixture. Regarding the characteristics of the silica-electrolyte mixture:

As to characteristic "(a)," Kishimoto and Ferreira teach away from using silica that is "suitably small so that the silica is not filtered by the separator of the plates."

Regarding characteristic "(b)," Kishimoto pertains to pre-formed plates and in Varma the silica-electrolyte mixture *does* gel before the plates are formed.

As to characteristic "(c)," in both Kishimoto and Varma, any gelling of a silica-electrolyte mixture that occurs is unrelated to the increase in specific gravity thereof due to sulfate release during plate formation.

In view of the foregoing, it is believed that claim 21 is allowable over the art of record. Based on their dependence of claim 21, claims 22-24 are likewise allowable. Furthermore, the recitation of additional patentable features in claims 22-24 provides a secondary basis for their patentabilty.

New claim 25 recites a method for manufacturing a battery:

> wherein the method comprises gelling an electrolyte within an absorbent separator and plates of the battery by contacting the separator and plates with a silica-electrolyte mixture and then forming the plates, wherein:
>
> (a) silica in the silica-electrolyte mixture has a particle size that is suitable for penetrating the separator and unformed plates such that a concentration of silica in a portion of the silica-electrolyte mixture that penetrates the separator and the un-formed plates is equal to a concentration of silica in a portion of the silica-electrolyte mixture that remains outside of the separator and the unformed plates; and
>
> (b) characteristics of the silica-electrolyte mixture substantially prevent the silica-electrolyte mixture from gelling until the plates have substantially formed.

None of the cited art, whether alone or in combination, discloses or suggests what is recited in new claim 25. In particular, none of the references suggest gelling an electrolyte within an absorbent separator and plates of the battery. As previously discussed, both Kishimoto and Ferreira teach away from using silica having a particle size that is suitable for penetrating the separator and unformed plates. Furthermore, neither Kishimoto nor Varma substantially prevent the silica-electrolyte mixture from gelling until the plates have substantially formed.

In view of the foregoing, it is believed that claim 25 is allowable over the art of record. Based on their dependence of claim 25, claims 26-28 are likewise allowable. Furthermore, the recitation of additional patentable features in claims 26-28 provides a secondary basis for their patentabilty.

Conclusion

It is believed that claims 1-12 and 21-28 now presented for examination are allowable over the art of record. A notice to the effect is therefore solicited.

Respectfully,

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From "Maintenance-Free Batteries
by D. Berndt

Eq.(2.6) is written with a 'plus', sometimes with a 'minus', sign (cf. the correspondin note with Eq.(6.10)).

Transposition of Eq.(2.6) represents the equilibrium voltage:

$$\boxed{E_o = -\frac{\Delta G}{n \cdot F}} \qquad (2.7)$$

Note: *Occasionally the equilibrium voltage is called the open-circuit voltage. But strictl speaking this term only means a voltage without external current flow, and may concern a mixed potential as well (cf. Fig.6.16). On account of secondary reactions, the rest potentials in batteries are usually mixed potentials, but this is not strictly observed i practical language.*

Thermodynamic quantities like ΔH and ΔG depend on the concentration of the reactin components as far as these are dissolved, according to the relation

$$\boxed{\Delta G = \Delta G_s + RT \cdot \sum\left[(a_i)^{i_i}\right]} \qquad (2.8)$$

with a_i = activity (cf. Note below) of the reacting component i
(approximately the concentration, Section 2.2.3.1),
i_i = number of equivalents of this component that take part
in the reaction,
R = molar gas constant for an ideal gas
($R = 8.3413\ J \cdot K^{-1} \cdot mole^{-1}$),
ΔG_s = standard value when all activities are unity.

Note: *The 'activity' a (in mole/dm^3) describes the 'effective concentration' and is define by the relation $a = f \cdot c$, where c represents the concentration (mole/dm^3) and f the activity coefficient. Thermodynamic rules that were derived for dilute solutions can be applie for more concentrated solutions, when instead of the concentrations the activities of th reacting substances are used. The activity coefficient f approaches the value one fo dilute solutions, but f can be very different from one in concentrated solutions (in certai solutions f attains values even > 1 (cf. [3]), but this does not concern the concentration used with batteries). The introduction of the activity means that the considered substanc is less effective (or more effective in case f > 1) with respect to the thermodynamic rule than would be expected from its actual concentration.*

This leads to an important relation concerning electrochemistry, namely th Nernst equation which describes the concentration dependence of the equilibrium voltage

$$\boxed{E_o = E_{o,s} + \frac{R \cdot T}{n \cdot F} \cdot \sum \ln\left[(a_i)^{i_i}\right]} \qquad (2.9)$$

$E_{o,s}$ is the equilibrium potential in standard conditions

Considering the relation log(x) = 2.303·ln(x) and the values for F and R (96.485 As per mole and 8.3413 J·K^{-1}·mole^{-1} respectively), equation (2.9) is simplified for 25 °C (298 K) to

$$\boxed{E_o = E_{o,s} + 0.05916/n \cdot \sum \log\left[(a_i)^{j_i}\right]} \qquad \text{(E in volt)} \qquad (2.10)$$

which can also be written

$$\boxed{E_o = E_{o,s} + 0.05916/n \cdot \sum j_i \cdot \log\left[(a_i)\right]} \qquad \text{(E in volt)} \qquad (2.10a)$$

Eq. (2.10) or (2.10a) shows that the equilibrium cell voltage is increased by 59/n mV when the activity (or approximately the concentration) of the dissolved substance is increased or reduced by one order of magnitude (depending on the sign of the charges). n means, as mentioned before, the number of exchanged electrons.

2.2.1.1. The Temperature Coefficient

The thermodynamic data determine the temperature coefficient of the equilibrium cell voltage according to the relation:

$$\boxed{\frac{dE_o}{dT} = -\frac{\Delta S}{n \cdot F}} \qquad (2.11)$$

Temperature coefficient as well as equilibrium voltage are often listed for 25 °C (= 298 K)(4). The equilibrium cell voltage at any temperature (T) is

$$\boxed{E_o(T) = E_o(298\ K) + (dE_o/dT) \cdot (T - 298)} \qquad (2.12)$$

assuming the temperature coefficient to be constant for the considered temperature range. This assumption represents a rough approximation, but for the battery systems considered the temperature coefficient of the equilibrium voltage is so small that its influence can usually be neglected in practice.

To evaluate the equilibrium voltage at any temperature, de Bethune(5) introduced the isothermal temperature coefficient $(dE_o/dT)_{iso}$. Its variation with temperature is described by a quadratic approximation, called the second temperature coefficient $(d^2E_o/dT^2)_{iso}$, which is also listed in the mentioned tables.

With the aid of both coefficients, the equilibrium potential $E_o(T)$ for temperature T against a standard hydrogen electrode at the same temperature can be calculated according to

$$\boxed{E_o(T) = E_o(298\,°K) + (dE_o/dT)_{iso} \cdot (T - 298) + 1/2 \cdot (d^2E_o/dT^2)_{iso} \cdot (T - 298)^2} \qquad (2.13)$$

The temperature coefficient used in Eq.(2.12) is called the thermal temperature coefficient $(dE_o/dT)_{th}$ in the above-mentioned tables.

From "Storage Batteries" by G.W. Vinal 4th Edition

TABLE 39. ELECTROMOTIVE FORCE OF THE LEAD STORAGE BATTERY AS A FUNCTION OF THE ACID CONCENTRATION

(All values in volts.)

Sp. Gr. 25° C / 25° C	Per Cent H_2SO_4	Determinations on Storage Batteries					Calculated from Electrode Measurements				
		Dolezalek Calculated to 25° C	Thibaut Calculated to 25° C	Vinal and Altrup at 25° C	Craig and Vinal at 25° C	Mean	Harned and Hamer at 25° C	Vosburgh and Craig at 25° C	Craig and Vinal at 25° C	Mean	Mean of All
1.020	3.05	.....	(1.833)	.....	1.855	1.855	1.855	1.856	.....	1.855	1.855
1.030	4.55	.....	(1.851)	.....	1.876	1.877	1.878	1.878	1.882	1.879	1.878
1.040	6.04	.....	(1.867)	1.890	1.892	1.892	1.895	1.893	1.896	1.895	1.893
1.050	7.44	1.906	(1.879)	1.903	1.905	1.905	1.908	1.909	1.908	1.908	1.907
1.100	14.72	1.963	(1.941)	1.956	1.962	1.960	1.960	1.962	1.961	1.961	1.961
1.150	21.38	2.012	(1.944)	2.000	2.005	2.005	2.005	2.006	2.007	2.006	2.006
1.200	27.68	2.054	2.043	2.045	2.050	2.048	2.050	2.049	2.051	2.050	2.049
1.250	33.80	2.098	2.094	2.091	2.098	2.096	2.097	.....	2.094	2.095	2.095
1.280	37.40	2.125	2.126	2.110	2.128	2.125	2.127	.....	2.121	2.124	2.125
1.300	39.70	2.143	2.148	2.138	2.148	2.144	2.147	.....	2.140	2.141	2.141

Notes on Table 39

1. All emf values have been read from curves for the percentages given in column 2, for which equivalent specific gravities at 25° C are given in col. 1.

2. Dolezalek's values in col. 3 have been calculated to 25° C and corrected for the difference between his value for the Weston cell and the value in use now.

3. Values in parenthesis, col. 4, were omitted in taking the mean values.

4. Determinations in col. 6 were made on cells containing pure lead grids; other cells are believed to have contained lead-antimony grids.

5. Electrode measurements are based on combining values of the separate electrode potentials, experimentally determined.

6. References: Dolezalek, *Theory of the Lead Accumulator*, p. 55, 1904; Thibaut, *Z. Elektrochem.*, *19*, 881 (1913); Vinal and Altrup, this book, 1st ed., p. 166, 1924; Harned and Hamer, *J. Am. Chem. Soc.*, *57*, 33 (1935); Vosburgh and Craig, *J. Am. Chem. Soc.*, *51*, 2009 (1929); Craig and Vinal, *J. Research Natl. Bur. Standards*, *24*, 475 (1940).